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INDEX NUMBER **G3.1**

HEATING THE HOME

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HEATING THE HOME
SMALL HOMES COUNCIL G3.1

HEATING SYSTEMS

A central heating system may include:

1) A means of burning or converting the fuel or energy (gas, oil, coal, electricity) to "heat"
2) A furnace or boiler to transfer the heat to the medium (air, water, or steam) that will be used to distribute the heat to various parts of the house
3) Heat distribution system (ducts or pipes)
4) Heat outlets (registers, diffusers, convectors, baseboards)
5) Controls

Non-central systems (self-contained) or room units may be placed within the space to be heated. These include reverse-cycle heat pumps, electric resistance heating in the form of baseboards, convectors, panels or embedded cables, or small units that combine many of the features of a central system.

A heating system may also include cooling features, humidifying equipment, and special air cleaning equipment. Some features are not available on all central or non-central (self-contained) systems.

The operating efficiency of a heating system depends upon the correct design, installation, and operation of the equipment chosen. The real cost of a heating system is not only the cost of the original equipment but also includes the cost of the fuel to operate the system and the cost of maintenance and replacement of the equipment. A "cheap" heating system will usually cost more over the life of the house than one properly designed and installed.

The construction of the house will also affect the operating efficiency of the heating system. Excessive heat losses through poorly fitted windows and inadequately insulated walls and ceilings will increase heating costs. Storm sash on windows and doors and insulation in walls and ceilings will pay for themselves in fuel savings and in added comfort both in winter and summer. (See SHC-BRC Circulars: F11.2, *Insulating Windows and Screens*; F6.0, *Insulation in the Home*; F7.0, *Chimneys and Fireplaces*; F6.2, *Moisture Condensation*; and Technical Note 3, *Insulation for Heating*.

CHOICE OF SYSTEMS

The decision as to the type of heating system to use will depend on such factors as:

1) initial cost and estimated life
2) maintenance costs
3) convenience
4) design of house
5) personal preference
6) adaptability to summer cooling

A number of systems are discussed and illustrated in this circular. In general, any of the systems shown will produce about equal comfort if they are properly designed and installed.

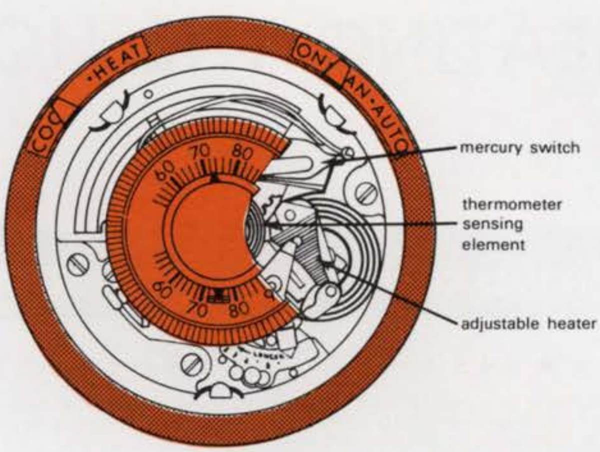
CONTROLS

The heating systems described in this circular are operated by automatic "controls". These devices include thermostats, fuel valves, safety controls, and switches to operate fans and pumps. They are designed to run the system automatically so that it functions only when heating is needed. This helps to keep the house at an even temperature, which adds to the comfort of the occupants and reduces the cost of operating the system.

The heart of the control system is the thermostat, essentially a temperature-sensitive switch that turns the heating system (or cooling system) on and off. Some thermostats are designed so that various stages or parts of the heating system can be turned on or off so that the heat input is "modulated" to match the heat loss of the house. Many thermostats are equipped with small heating elements called an-

FUELS

The systems described in this circular can use any fuel (natural gas, propane, coal, oil, electrical energy) with the few exceptions noted in the accompanying discussions. The fuel used will depend primarily on its availability and the relative cost when compared to other available fuels. To some degree, the convenience offered by the fuel may affect choice, although most modern fuels offer about equal operating convenience. The equipment selected should be designed for the intended fuel to give the highest operating efficiency.

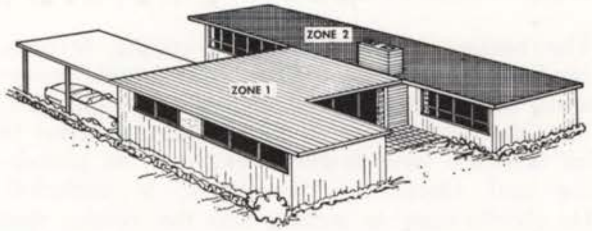


THERMOSTAT

ticipators. The anticipator raises the temperature within the thermostat case, giving it a false reading and causing it to turn the system off before the room reaches the desired temperature. The residual heat in the system will then bring the temperature up to the desired point. If there is not sufficient residual heat, the thermostat will sense the deficiency and turn the system on again. In this way the desired temperature is reached in small steps so that the house is not overheated, with a resultant waste of fuel and occupant discomfort.

In many instances, one thermostat is used to control the temperature in several rooms or the whole house. Actually, it can sense the temperature only in the room where it is located. For this reason it is important that the thermostat be located either where the temperature is representative of the whole house or where temperature control is most important. Locate the thermostat at a height of 2½ to 4 feet above the floor. Avoid locations on outside walls, near outside doors, or in bedrooms where windows may be left open. Likewise, do not place it near heat outlets, behind doors, on walls that receive heat from the sun or fireplace, or on walls that house heating pipes, ducts, or chimneys. Avoid locations that may interfere with furniture placement. Lamps, TV sets, or radios under a thermostat will give it false readings and result in poor control of the heating system.

In some cases, it may be desirable to divide the house into two or more zones for heating (or cooling) control. With non-central systems (such as electric resistance baseboard or ceiling cable), this is relatively easy to achieve. With ducted or piped systems, the distribution lines must be specifically designed for this purpose. Zoning is used to help maintain the same temperature in various parts or levels of the house. Zoning should be considered for multi-level or large houses, or when there are unusual sun or wind exposures.

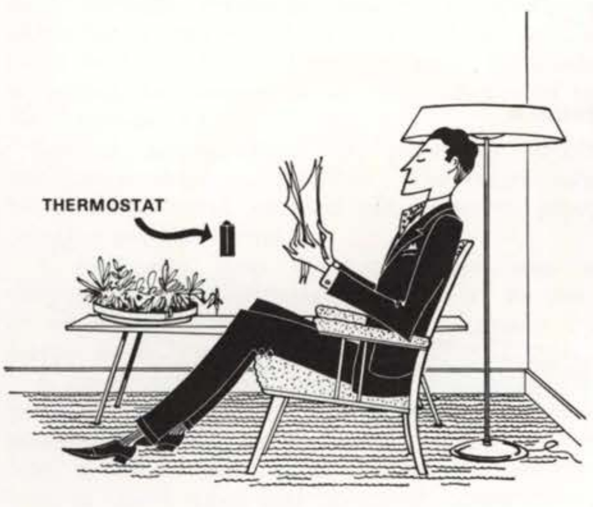


Zone control makes it possible to maintain an even temperature in rooms with varying sun and wind exposure

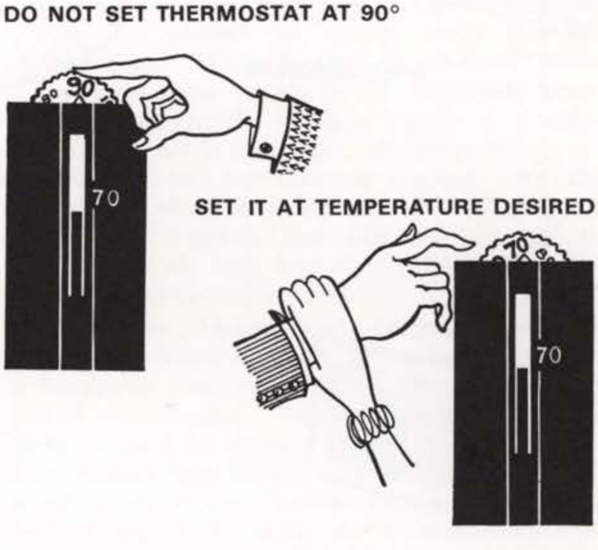
A thermostat located in each zone controls a solenoid valve in the line serving that area in a hot water system or a motorized damper in the main duct going to the area in a warm air system. The water circulating pump or burner is turned on when any zone calls for heat.

The thermostat should be set at the point at which the occupants are most comfortable and left at that setting except for special circumstances. These special times occur at very cold outside temperatures, when heating is almost continuous. At that time, thermostats equipped with anticipators may have a tendency to "droop" and maintain a temperature a few degrees below the setting. In these cases, the thermostat setting will have to be adjusted. A setting above the desired temperature will not make the temperature raise any faster nor will a low setting cause the house to cool any faster. The speed with which the temperature in a house will respond to a change in the thermostat setting will depend on the type of heating system and the construction of the house.

The thermostat setting may be lowered 5 to 10 degrees during sleeping hours. Research indicates a savings of 5 to 10% in operating cost with night set-back.



Thermostat should be located 2 to 4 feet from floor



A thermostat setting higher than 72° will not make the room temperature reach 72° any faster

INSTALLATION

The heating contractor should supply layouts, service agreements, guarantees, and operating instructions for all pieces of equipment. The heating contractor should also indicate in his estimate how much work, such as plumbing and electrical connections, is included. He should state in writing that the system that he will install will maintain a specified interior temperature at specified outdoor temperature and wind conditions.

Warm-air systems should be designed and installed as recommended in the manuals originally issued by the National Warm Air Heating and Air Conditioning Association. Copies of the manuals are available from the National Environmental Systems Contractors Association, 221 North LaSalle Street, Chicago, Illinois 60601.

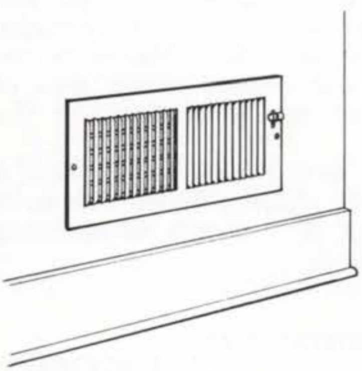
Hot-water systems should be designed and installed as recommended by the Hydronics Institute. Copies of the manuals are available from the Hydronics Institute, 35 Russo Place, Berkeley Heights, New Jersey 07922.

Manuals for the design and installation of electric systems are generally available from local utility companies and from the Edison Electric Institute, 750 Third Avenue, New York, New York 10017.

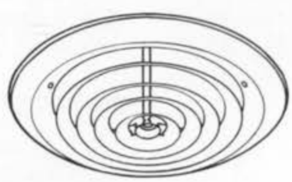
WARM AIR SYSTEMS

Warm air systems require an outlet to deliver the heated (or cooled) air to the room or space. The outlets may be floor or wall registers or ceiling diffusers. Return-air intakes are necessary to return the air to the furnace to be reheated, filtered, humidified, and redistributed to the supply outlets.

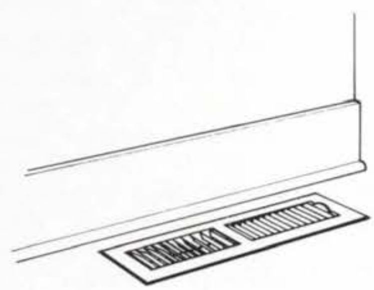
In general, supply outlets should be located at the outside walls, preferably under windows or large glass areas, and return-air grilles should be located either high or low on the wall. Ceiling diffusers can be used on the second floor of two-story homes, and on the upper floors of multi-storied buildings as long as there are heated spaces below the floor and there are no large glass areas that can cause drafts across the floor.



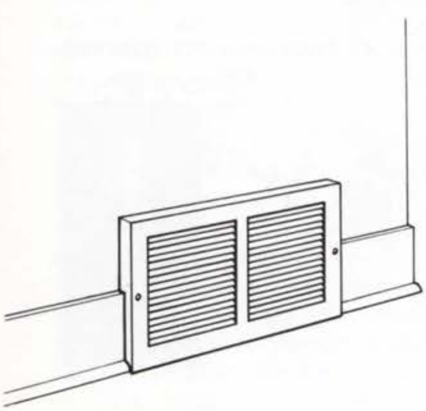
WALL REGISTER



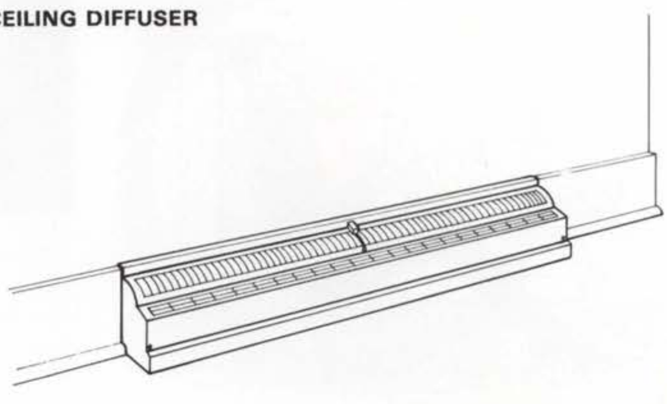
CEILING DIFFUSER



FLOOR DIFFUSER

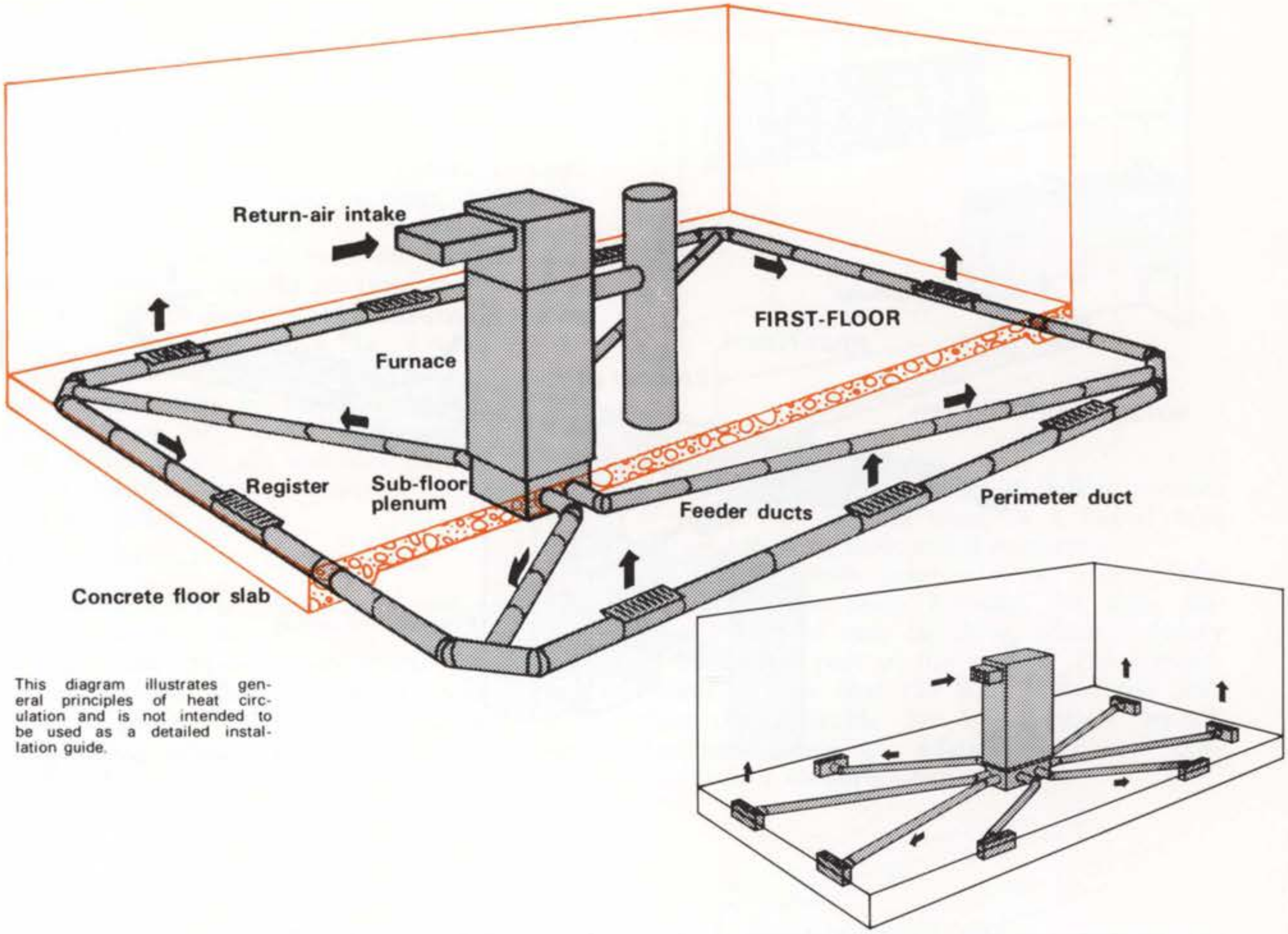


RETURN GRILLE



BASEBOARD DIFFUSER

PERIMETER-LOOP AND -RADIAL SYSTEMS



Perimeter heating systems with a down-flow furnace are intended for basementless houses built on concrete slabs. The warm air from the furnace is circulated through a duct system which is embedded in the concrete slab. The warm air in the ducts is discharged into a room through outlets—either floor or baseboard diffusers placed along the outside walls, usually below windows. Air is taken back to the furnace through return-air intakes at locations either on an inside wall or in a hallway ceiling close to the furnace. Provision must be made to permit the passage of air from all rooms to the return-air intakes.

Several arrangements of perimeter ducts and feeder ducts are possible. The ducts may be of sheet metal, vitrified tile, concrete pipe, or other precast forms.

A perimeter loop heating system uses a duct system that encircles the slab at its outer edge and is connected to the furnace by feeder ducts.

A perimeter radial system is similar to the perimeter loop system. However, floor temperatures will not be as uniform as with the loop system. The radial system can also be used in crawl space and basement construction. It is more economical to install than a perimeter loop system.

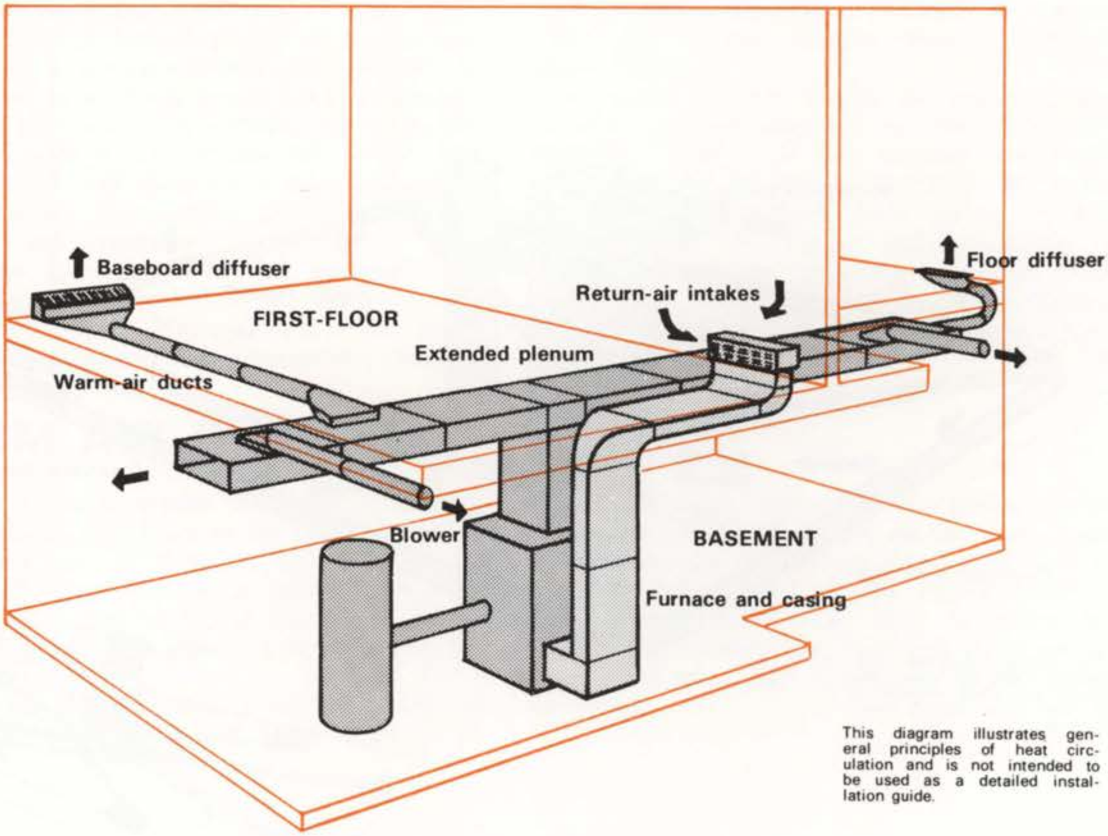
A perimeter heating system:

- Is designed to eliminate cold floors and retain all the advantages of a forced warm air heating system.
- Is economical to install.
- Needs very little floor area, since a down-flow-type furnace has been designed for basementless installations. These furnaces may be placed in closets with minimal clearances. When located in confined areas, provision must be made for supplying combustion air to the furnace burner if a combustible fuel is used (gas, oil, propane).
- Can be used for summer cooling with the addition of cooling equipment. Floor registers or registers that can be adjusted to blow the air high into the room toward the ceiling are recommended.

Maintenance: Motor and blower must be lubricated, filters cleaned or replaced, and if a burner is used, it must be cleaned and adjusted periodically. Supply outlets and return grilles should be cleaned yearly.

Design and Installation: Use Manual K, *Equipment Selection and System Design Procedures,* and Manual 6, *Adjusting Air Conditioning Systems for Maximum Comfort*, issued by the National Warm Air Heating and Air Conditioning Association (See page 4).

EXTENDED-PLENUM SYSTEM



Air circulation in the extended-plenum system is maintained by a blower (fan) in the furnace. Air is warmed by the heated surfaces of the furnace and then distributed to the various rooms through supply ducts and supply outlets. The blower also draws the room air back to the furnace through the return-air intakes and return ducts to be filtered and reheated. After the room air has been heated and filtered, it is redistributed to the rooms.

Adjustable registers and diffusers located on the outside wall at floor level, preferably below windows, are recommended for heating. The supply outlets so installed will curtain the cold outside wall with warm air and will not discharge directly on the occupants. Ceiling diffusers may be used in rooms, such as second floor bedrooms, that do not have large glass areas and are located over heated spaces.

For small houses where doors to rooms are left open, a single central return-air intake may be sufficient. In larger structures and in homes where room doors will be kept closed, multiple return-air intakes may be necessary. The return-air intakes are usually located on inside walls, or in the ceilings of hallways.

An extended-plenum system:

- Responds rapidly to changes in outdoor temperature.
- Is economical to install.
- Is adaptable to crawl-space (with down-flow furnace) or basement houses and large structures, and to the heating of basement rooms.
- Can be adapted to summer air conditioning with the addition of cooling equipment. (Floor registers or registers that can be adjusted to blow the cooled air high into the room toward the ceiling should be used for supply outlets. The extended plenum should be lined with duct insulation.)
- Can be provided with humidification equipment.
- Can provide controlled outdoor ventilation through the duct system.
- Can include electronic air cleaning devices.

Maintenance: Motor and blower must be oiled, filters cleaned or replaced, and the furnace burner inspected and adjusted periodically. Supply outlets and return grilles should be cleaned yearly.

Design and Installation: Use Manual K, *Equipment Selection and System Design Procedure,* and Manual 6, *Adjusting Air Conditioning Systems for Maximum Comfort,* issued by the National Warm Air Heating and Air Conditioning Association (See page 4).

HOT WATER SYSTEMS

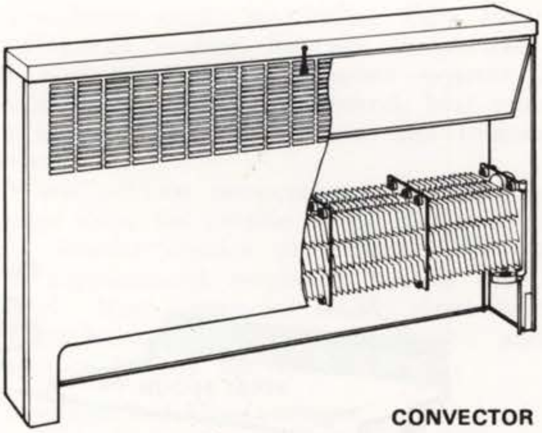
Convectors and baseboard units are devices for transferring heat from the water to the air of the rooms.

Convectors

Convectors consist of a core (either a small tube or a hollow cast-iron section), which has a number of thin "fins" or metal plates attached to it. Hot water heats the core and fins, which, in turn, warm the air passing over them.

The core and fins are enclosed in a cabinet, causing a more effective air flow over the heated surfaces than if they were exposed.

Convectors may be installed against an outside wall, or they may be recessed into the wall with only the air openings exposed. Preferred location for a convector is under or near a window.



CONVECTOR

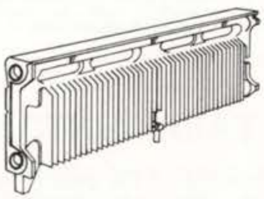
Baseboard Units

Baseboard heating units are sometimes used with hot-water systems.

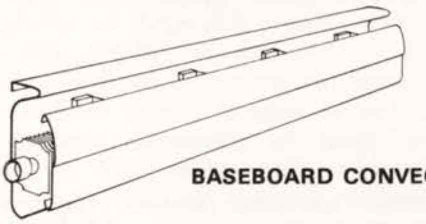
These units replace conventional baseboards and are installed along the outside walls of each room in place of the usual wood baseboard. Hot water circulating through the sections transmits heat to the room.

Baseboard units are made of hollow sections of either cast iron or steel, or a finned tube placed behind a sheet-metal enclosure.

Baseboard units achieve even temperatures throughout the room because the units distribute the heat near the floor, which normally is the coolest part of the room. The concentration of heat near the floor makes the units especially desirable for basementless houses. Baseboard units are adaptable to new construction or modernization work.



REAR VIEW OF FIN BASEBOARD UNIT



BASEBOARD CONVECTOR

FAN-COIL HEATING SYSTEM

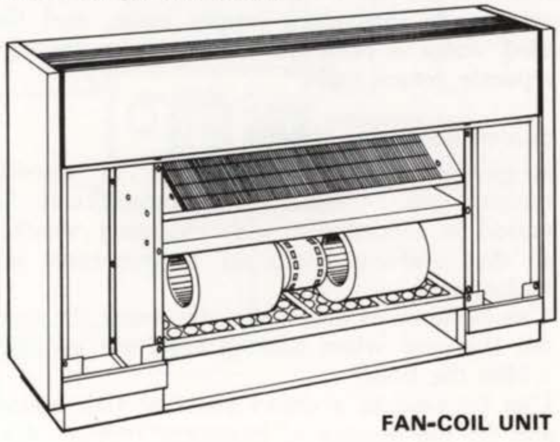
The fan-coil unit is used primarily when both heating and cooling are to be provided. Water is heated (or chilled) at a central point and then pumped through the pipes to the terminal units located in the rooms. The fan-coil unit consists of a finned-tube coil and a fan section. The fan section circulates air from the room or from outdoors over the coil section, thus heating or cooling the air. The recirculated air is usually filtered as it is drawn into the enclosure.

The piping system may be a one-pipe system if only heating is to be supplied, or a two-pipe system for heating and cooling. Three- and four-pipe systems can also be used, and will add to the flexibility of being able to heat and cool in different rooms at the same time. The temperature in the room may be controlled by valves on the unit or by a thermostat located in the room.

Fan-coil units are not generally used in houses. They are readily adaptable to apartment houses. Since the fan is located in the room, they may be somewhat noisier than other central systems.

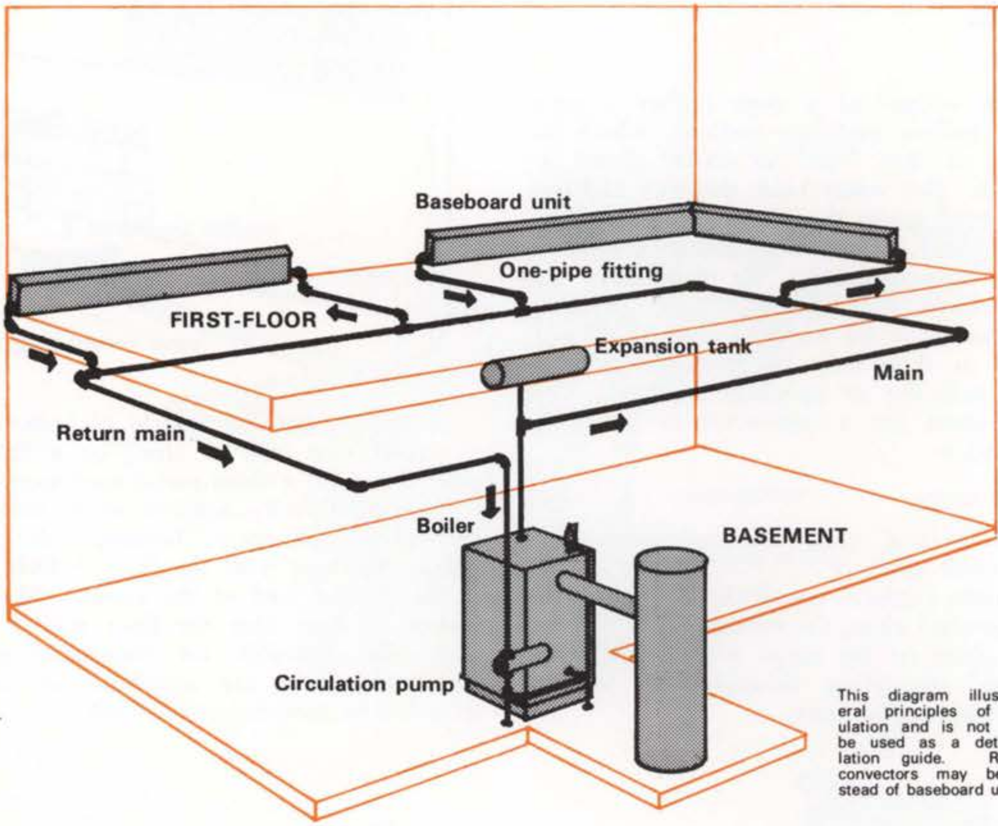
Maintenance: In addition to the items mentioned for the hot-water heating system on page 8, the filters at the units must be cleaned or replaced periodically and the fan motors must be lubricated.

Design and Installation: Fan-coil heating cooling systems should be designed and installed by professionals.



FAN-COIL UNIT

FORCED HOT WATER HEATING SYSTEM



This diagram illustrates general principles of heat circulation and is not intended to be used as a detailed installation guide. Radiators or convectors may be used instead of baseboard units.

In a forced hot-water system, the water is heated in the boiler and is forced through the pipes (mains and risers) to the room and heat outlets. The circulation of water is produced by the action of an electric pump at the boiler.

Two basic types of piping layout are common:

The one-pipe system (shown above)—This has a single pipe or main which supplies the heated water to the baseboard units (or convectors or radiators) and also returns the cooled water from the units to the boiler.

The two-pipe system—This system has two mains. The heated water is supplied to room heating units through a supply main, and the cooled water is returned to the boiler through a separate return main.

A forced hot-water system:

- Responds rapidly to changes in outside temperature. Water temperature can be varied in accordance with changing weather so that uniform room air temperatures are maintained.
- Can be used to heat domestic water throughout the year when heating coils are installed within the boiler.
- Can be used in a crawl-space or slab houses and for the heating of basement rooms. Circulation of water by means of the pump makes it possible to locate baseboard units or convectors either above or below the level of the boiler.
- Makes possible a large amount of usable basement space, since small (½"-1") pipes can be used for the mains and risers.

Heat Outlets: Convectors or baseboard units may be used.

Maintenance: Water pressure in system must be checked, motor oiled, and room heating units vented unless automatic vents are used.

Design and Installation: Use Hydronics Institute Installation Guide 200, *Residential Hydronic Heating Systems*, published by the Hydronics Institute. (See page 4 for address.)

DOMESTIC HOT WATER

With some types of boilers, it is also possible to heat water for domestic use. This eliminates the need for a separate water heater. (See SHC-BRC Circular G5.0, *Plumbing* for a more thorough discussion.)

ELECTRIC HEATING SYSTEMS

Electricity may be thought of as a "fuel" much the same as coal, oil, or gas. If it is used to "fire" a furnace or boiler, then heating with electricity is about the same as with other fuels.

Resistance Heating

Electric baseboards are similar to the baseboards described on page 7 of this circular except that instead of hot water passing through the baseboard they contain an electric heating element very similar to the element used on an electric range. The units installed in each room or area are controlled by a separate thermostat mounted on the wall or installed as part of the baseboard unit.

Furnaces and boilers that use electricity as a "fuel" operate in the same fashion as other equipment using combustible fuels, with electrical resistance elements replacing the combustion chamber. Heat is distributed as shown elsewhere in this circular.

Other resistance-type heaters are available in the form of panels of glass or metal that are mounted on the wall or ceiling; resistance cables imbedded in the ceiling; units that have a small fan which circulates the heated air; and water-filled baseboards in which the water is heated in the baseboard by resistance elements similar to those used in a water heater. Also available are resistance units that may be inserted in the branch supply ducts of a central air duct system.

ELECTRIC HEAT PUMP

The electric heat pump is essentially a reversible refrigeration unit. In the summer it operates as a typical air cooling unit. Heat is extracted from the air inside the house and discharged outside the house. In the winter, the process is reversed. Heat is extracted from the outside air, ground, or well water, and is then distributed in the house, usually by means of a typical duct system as described under warm air heating systems.

Installation costs are higher than for resistance-type heating, but are comparable to the cost of installing separate systems for heating and cooling. In general, heat pumps are less expensive to operate than resistance heaters.

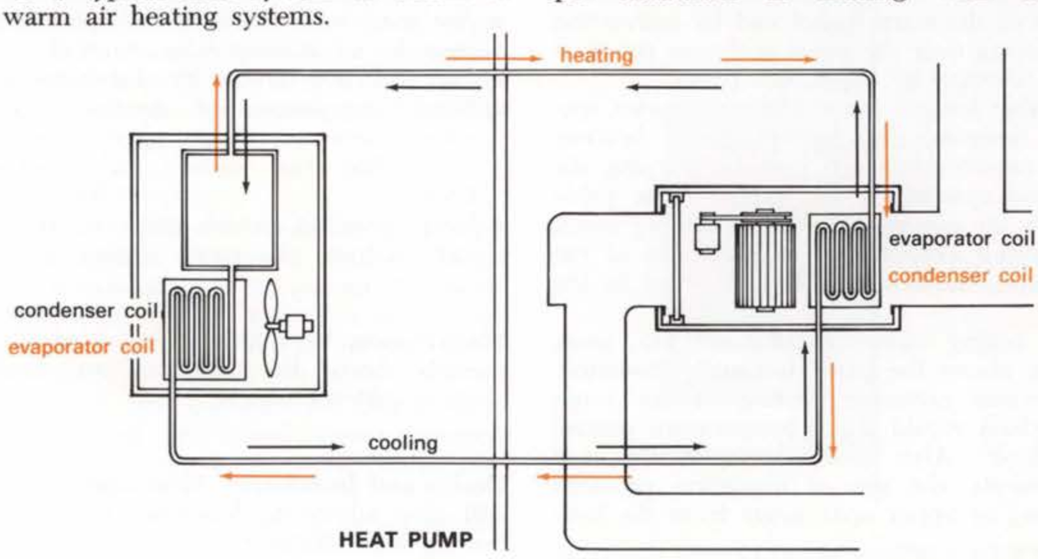
When outdoor temperatures are low, heat pumps using the outside air or the ground as heat sources operate at reduced efficiencies and supplemental resistance heaters are required. Heat pumps are usually sized for the cooling load, and in northern climates added resistance heaters are necessary.

Advantages and Disadvantages

Heating with resistance heaters has the advantages of lower installation costs, no combustion of fuel in the house and therefore less noise and less maintenance, no space required for fuel storage, and no space required for duct work, piping, boiler or furnace, or chimney. They also offer the advantage of complete room-by-room control of temperature. Heat pumps have the advantage of all-year climate control in one unit.

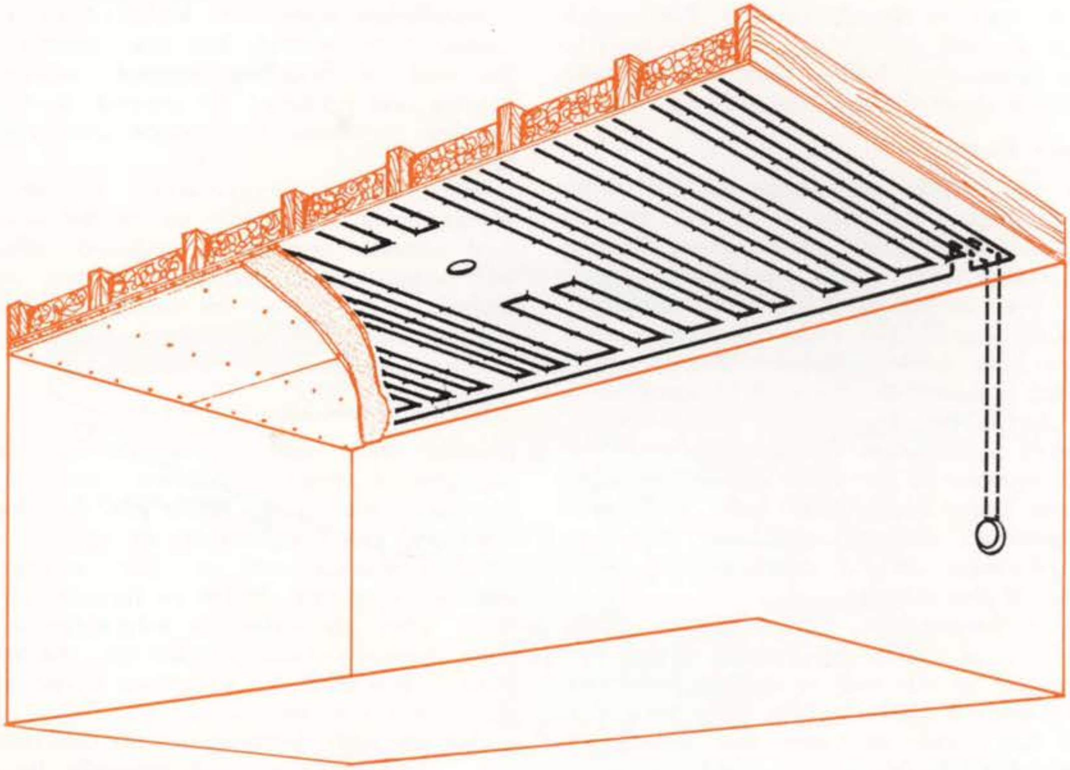
Heating with electricity has its disadvantages, too. Operating costs will generally be higher than other fuels except where electric energy is available at favorable rates. More insulation will usually be required to keep operating costs from becoming excessive. When power failures occur, heating is not possible. (This is true, however, of most automatic systems.) With resistance-type heaters not employing moving air, control of humidity is difficult. In houses of tight construction, humidistat-operated ventilating fans may be required.

Design and installation of electric heating systems should be done by competent, experienced personnel. Many utility companies will, upon request, give advice to those people interested in heating with electricity.



HEAT PUMP

ELECTRIC CEILING CABLE SYSTEM



This diagram illustrates general principles of heat circulation and is not intended to be used as a detailed installation guide.

Electric ceiling-cable systems can provide satisfactory heating. Electric resistance cables are attached to the ceiling lath and embedded in plaster, or the cables may be "sandwiched" between two layers of drywall. The panel attains a temperature of about 100° to 120°F. It is also possible to purchase a drywall material with the cables already embedded in the board.

Heating of the room takes place by the radiant effect of the warm panel and by convection of air moving over the panel and over the floor which is warmed by the radiant panel.

The cable lengths are made up of wire specifically designed for use in panel heating. Heating requirements are met by varying the length and spacing of the cable. The cable assemblies are equipped with non-heating leads, which permit connections to be made at the thermostat without having heated wires in the wall.

When ceiling cable installations are used, the space above the panel is usually insulated. This prevents excessive heating of the room above, which would make temperature control very difficult. Also, when this system is used in apartments, the use of insulation prevents the heating of upper apartments from the lower floors.

Lightweight, acoustic, or insulating plasters cannot be used over the cables, and caution must be used during construction to protect the cables from damage.

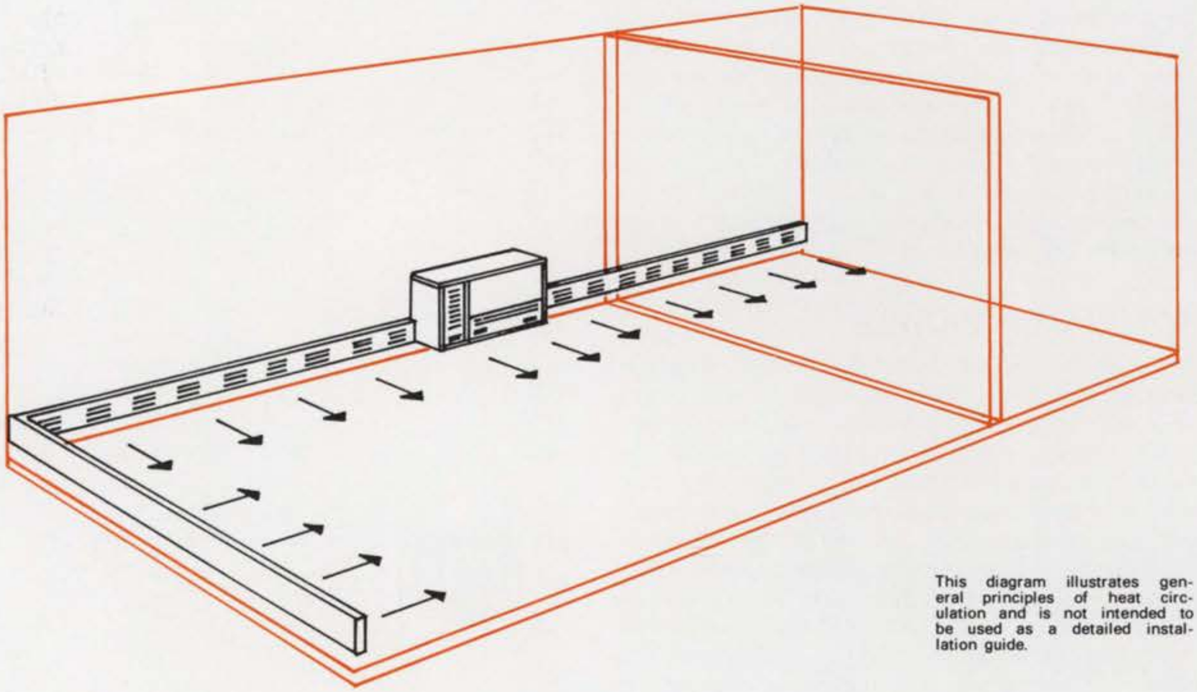
Ceiling-cable systems:

- Are usually less expensive to install than other electric-resistance heating systems.
- Do not use any floor space.
- Are used with thermostatic controls to give room-by-room temperature control.
- Do not interfere with furniture location.
- Need supplementary heating equipment when there are large glass areas in the room that can cause drafts across the floor.
- Limit possible modifications to ceiling and light fixture placement during remodeling.

Maintenance: Very little if any needed. Thermostats should be inspected periodically for worn or pitted contacts.

Design and Installation: Many utility companies will give advice to homeowners interested in heating with electricity.

SELF-CONTAINED SYSTEMS



This diagram illustrates general principles of heat circulation and is not intended to be used as a detailed installation guide.

In addition to the electric self-contained systems, it is possible to install units that use natural or manufactured gas for fuel. In appearance, these units look like convectors or fan-coil units. Each unit contains a small furnace that heats the air circulated through the enclosure by a fan section. Air for combustion of the fuel is drawn in from outdoors. The combustion air is never in contact with and cannot mix with the air in the room.

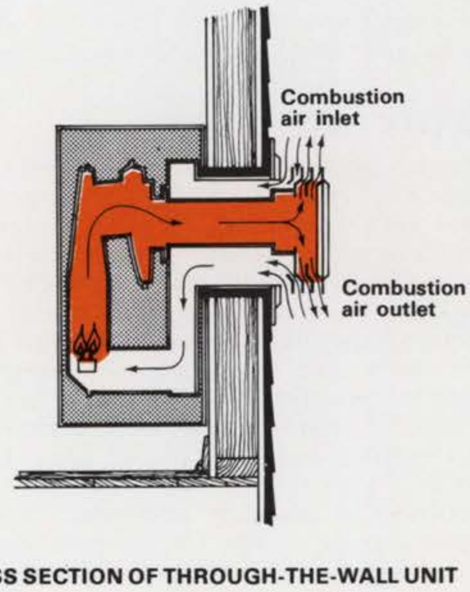
Some units are available with special duct sections so that warmed air can be circulated to other parts of the room or to other rooms nearby. The distance that the air can be ducted is limited.

A self-contained system:

- Is easy to install in any room. It is particularly convenient to use in room additions when it is not possible to extend the main heating system. It is also convenient for use in rooms that need not be heated all of the time, such as enclosed porches.
- Can be used with conventional thermostatic controls, giving individual room control.
- Can be used in basement rooms for supplementary heating.
- Can be purchased with cooling equipment in the same cabinet.

Maintenance: Similar to requirements for warm-air furnace.

Design and Installation: Heat loss should be estimated from procedures of National Warm Air Heating and Air Conditioning Association. Equipment should be installed by a competent heating contractor.

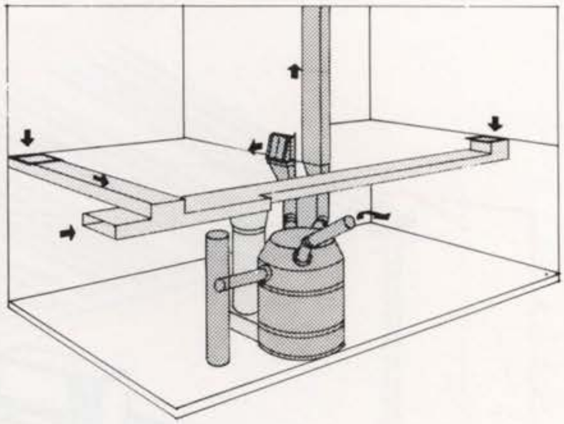


CROSS SECTION OF THROUGH-THE-WALL UNIT

SYSTEMS FOUND IN OLDER HOMES

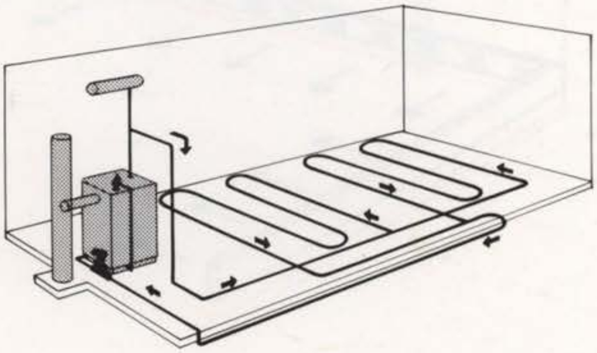
GRAVITY WARM AIR

Air circulation is achieved by the fact that warm air expands and rises upward and cool air contracts and flows downward. Gravity systems have no motors or electrical connections other than those required by burner controls, if any. The operation is very simple, but it is only adaptable to very compact basement houses. Comfort conditions are not always good since the air must be introduced at the inside walls. Gravity systems may be updated by the installation of blower units.



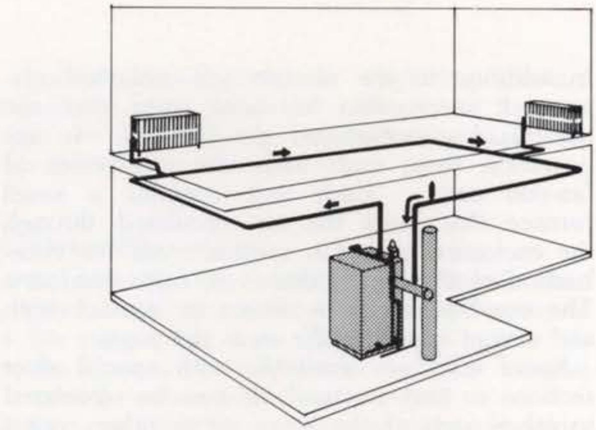
HOT WATER PANELS

A boiler is used to heat the water circulated through the floor, wall, or ceiling, which acts as a radiant panel. No other radiators or terminal vents are needed. The heat from the water is transferred from the pipes to the panel surface and then heats the room by radiation and convection. The surface temperature of floor panels cannot be maintained above 85°F without discomfort, which can be a limiting factor if the rooms have high heat losses. Wall or ceiling temperatures may be as high as 115-120°F. Control of the panels is difficult in mild weather.



STEAM SYSTEMS

Steam is generated in a boiler and rises by natural movement to the radiators through risers. The steam cools in the radiators, condenses into water, and returns to the boiler through the same pipes if a one-pipe system is used or through another pipe if a two-pipe system is used. Steam systems are simple and do not require motors or electrical connections except for controls and automatic burners. They can be used to heat domestic water. Temperature control is difficult in the one-pipe systems usually used in residential installations.



GRAVITY HOT WATER

The water in a gravity hot water system circulates as a result of changing density. The warmer water rises and displaces cooler water in the system, forcing it to return to the boiler. *Closed systems* have expansion tanks located near the boiler and will operate at higher temperatures than open systems without having steam form. The higher temperatures permit the use of small radiators. *Open systems* have an expansion tank located above the highest radiator, and the water is "open" or exposed to the air. A gravity system is simple and requires a minimum of fittings. It does not need motors, pumps, or electrical connections except for automatic burners.